Usability Enhancements for 3-D Photonic Design Tools

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A number of algorithms have been created to model novel and LLNL-specific devices. These algorithms were implemented in a suite of tools to model full 3-D, time-domain, nonlinear, photonics devices. This project was initiated to transition the suite of research codes to production codes, usable by a wider audience. The enhancements to the research codes will provide a set of packaged design tools that can be run on a variety of serial and parallel computers.

Project Goals

The capability for engineers to model novel 3-D photonic devices in the time domain requires usable and efficient simulation codes. The specific tasks of this project include the implementation of the existing algorithms, improving user interfaces, porting the codes to more common platforms, and running examples. The software that this team has written will be made widely available throughout LLNL on different computer architectures.

Relevance to LLNL Mission

Simulation is a core competency of LLNL, and this work enhances the ability of its engineers to model a broad class of devices. Potential users include the photonic designers in NIF (high speed diagnostics), DNT (weapons safe optical sensors), DHS (radiation sensing), NSA (gain quenched laser logic), NAI (fiber amplifiers), and PAT (components for the linac coherent light source).

FY2006 Accomplishments and Results

The existing algorithms have three main areas: enhancement of the full vectorial, 3-D time-domain code EMSolve; enhancement of the 3-D beam propagation quench suite of codes; and the creation of a code to model semiconductor physics.

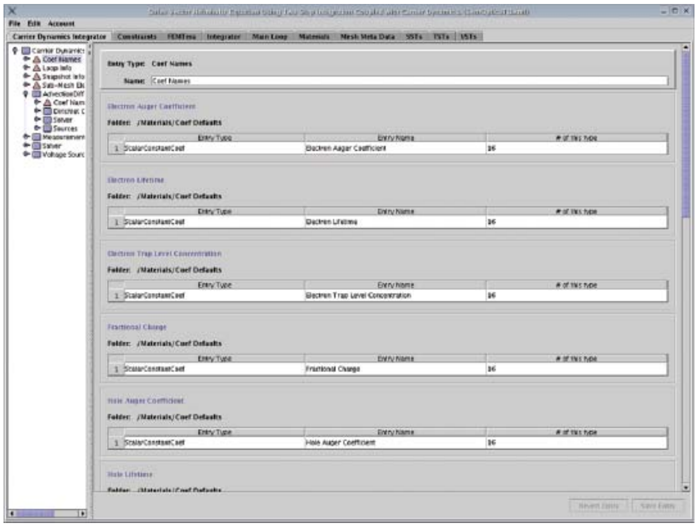

Figure 1. Configuration system. The EMSolve code uses an XML-based configuration system, which enables fast simulation configuration and easy integration of new code features. The GUI uses java for cross-platform portability.

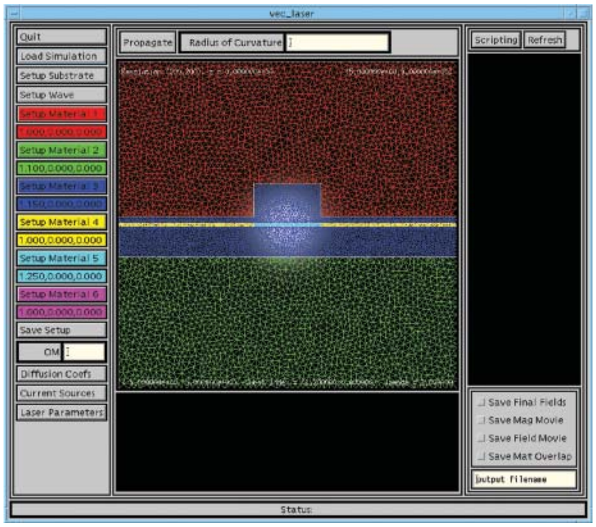

Figure 2. vec_laser GUI showing initial conditions for simulation of an optical amplifier. The mesh is shown in color and the input waveform is shown in grayscale.

The EMSolve code includes a number of enhancements to simulate photonic devices. A coupled carrier diffusion integrator/electrodynamics solver has been implemented for photonic integrated circuit simulations. In order to make this coupled system more efficient, a sub-mesh object was implemented to separate the carrier dynamics simulation grid from the full structure. In addition, efficient vector operations and finite element library optimizations were implemented, providing a 12x speed improvement. Figure 1 shows the configuration system. Adding a new component adds a tab to the configuration window. This advanced model was used to study THz photoconductive antennas.

In a separate integrator a polarization model was implemented using both 2- and 4-level absorption/gain models. These polarization models will be used to simulate 3-D vertical cavity, surface-emitting lasers (VCSELs).

The quench suite of codes has been augmented with a narrow bandwidth beam propagation method (BPM) code with coupled carrier diffusion called vec_laser. The GUI produced for this code is shown in Fig. 2. The vec_laser code has been parallelized and ported to run on Intel-based parallel machines.

In the Intermixed Quantum Well Physics modeling code the accomplishments for this year include implementation of Version 2 for calculation of complex permittivities in quantum wells using a quantum mechanics approach. Carrier induced effects are included: bandgap shrinkage is implicit in the calculation of electron wavefunctions using an iterative approach to solve Schroedinger-like and Poisson equations including many-body carrier effects, bandgap filling, and free-carrier absorption effects. Excitonic effects are also included. The potential distribution in the diffused well at quiescent state, the carrier density distribution formulation, the iterative formulation of quasi-Fermi levels, the interband absorption integrated with exciton saturation effects, and the integration limits have all been updated. Figure 3 shows the potential in a diffused quantum well for different diffusion lengths. Figure 4 shows the trend of absorption for a TE polarization in an AlGaAs/GaAs quantum well; with increasing carrier density saturation of the light-hole excitonic peak occurs.

Related References

1. Koning, J. M., "Terahertz Photo-Conductive Antenna Array Power Scaling Simulations," *Proceedings IEEE APS*, pp. 2631-2634, 2006.
2. Koning, J. M., D. A. White, R. N. Rieben, and M. L. Stowell, "EMSolve: A Three Dimensional Time Domain Electromagnetic Solver," *5th Biennial Tri-Lab Engineering Conference*, Albuquerque, New Mexico, October 21-23, 2003.
3. Bond, T. C., and J. S. Kallman, "Time-Domain Tools for the Investigation of Gain-Quenched Laser Logic," *International Semiconductor Device Research Symposium*, Washington, DC, December 10, 2003.

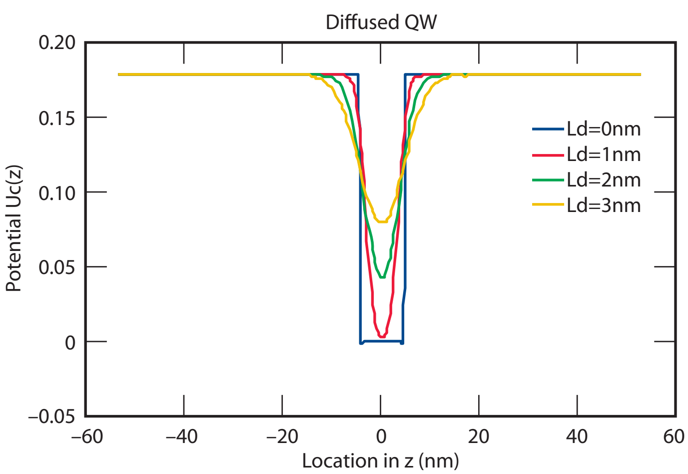

Figure 3. Potential distribution for the conduction band in a diffused quantum well for different diffusion lengths, Ld. The longer Ld, the smoother the transition from well to barrier and the wider the gap.

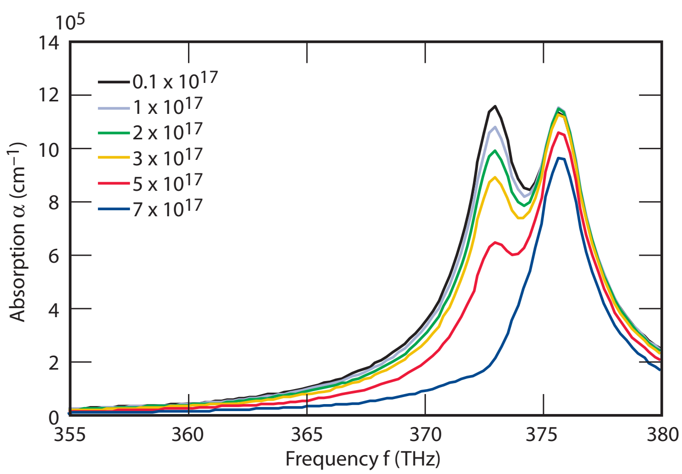

Figure 4. TE absorption in a 7-nm AlGaAs/GaAs well.